Project Proposal

Hybrid Electric Motorcycle

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This document details the preliminary proposal for the Hybrid's Angels Senior Design Project. It will address some the goals set by the group, the available technologies to achieve these goals, and the engineering issues that will need to be addressed.

1 CONTENTS

2 INTRODUCTION

From August 2007 to May 2008, a group of senior electrical engineering majors at the University of Notre Dame began construction on a hybrid motorcycle. Over the course of the year, they successfully converted a 1983 Yamaha Seca into a battery powered vehicle; however, they were unable to meet the ambitious goal of mechanical power system hybridization. In this proposal, Hybrid's Angels will delineate a plan to realize this goal in addition to fixing and enhancing current issues with the motorcycle's current design.

3 PROBLEM DESCRIPTION

The phrase "going green" has gained widespread popularity in recent years. As uncertainty mounts about the effects of carbon emissions on the earth's future, increased pressure is falling upon individuals around the world to reduce their carbon footprints. This can be accomplished in a wide variety of ways from an increased devotion to recycling to simply turning off a light when not in use. Energy conservation and decreased emissions are more important now than ever because evidence of the negative effects of our hitherto wasteful nature is finally beginning to manifest itself. One of the major sources of this waste is a product that has become fundamental to our daily activities – the car. Automobiles have been a staple of transportation for decades, and the carbon dioxide and carbon monoxide that they billow through their exhausts is a colossal part of our problem. A great deal of stress has been placed upon auto manufacturers to trim their vehicles' emissions, and thus far the most popular response has been the introduction of the hybrid vehicle. Although certainly not the solution to all of the energy ills, hybrid technology will act as a critical transition technology until cleaner, more efficient sources are implemented.

4 PROPOSED SOLUTION

While hybrid vehicles are not completely independent of fossil fuels, they are much more "green" than gasoline powered engines. The electricity used to power the batteries in a hybrid is likely to come from a power plant that burns fossil fuels, but even that situation is much more efficient and environmentally friendly than the combustion engine of a car. In addition, a hybrid vehicle will not produce any emissions while running off the batteries. So why not just build an electric vehicle? The range and charging time of current electric automobile technology cannot compete with traditional gasoline powered engines used in most cars. A hybrid is therefore the best solution because it is a compromise between current gasoline powered automobiles and the emission-free vehicles of the future.

Last year, a group of senior electrical engineering majors, the Lightning Riders, built a prototype electric motorcycle. For our project, we will modify and improve the electric motorcycle built by the Lightning Riders by turning it into a hybrid motorcycle.

5 DEMONSTRATED FEATURES

Hybrid's Angels' overarching goal will be to make a working hybrid motorcycle. Still, the group intends to fix and improve some of the features, which were implemented to varying degrees of success in the Lightning Riders' model. Hybrid's Angels expect to demonstrate the following features in May, proving that the group arrived at a solution to the initial problem:

5.1 ACHIEVE PERFORMANCE REQUIREMENTS

- In hybrid mode, travel at least 20 miles before refueling and/or recharging
- Able to maintain top speed of at least 50 miles per hour

5.2 HYBRIDIZE THE MOTORCYCLE

- Mount generator on the motorcycle
- Interface the generator with the charging circuitry

5.3 DESIGN FUNCTIONING USER INTERFACE

- Power monitoring circuitry
    - State of charge
    - Efficiency
- Range Calculations
- Critical Conditions
    - Temperatures
    - Voltages
- Digitally implemented speedometer

5.4 ENHANCE CHARGING CIRCUITRY

- Allow for batteries to be charged from both the wall socket as well as a generator system
- Duplicate the charging circuitry to allow for additional amperage to be drawn
- Alter the programming so that the batteries charge more safely and intelligently

5.5 IMPLEMENT DC TO DC CONVERTER CIRCUITRY

- Draw power equally from all batteries to power various motorcycle components
- Seamlessly allow for motorcycle components to be charged from AC source when present

5.6 ADDITIONAL MINOR FEATURES

- Make the design street legal
    - Implement working headlight interfaced to cycle circuitry
    - Install taillight, brake light, front brakes, mirrors, and a horn
- Utilize alternative energy source(s) for enhanced efficiency

- Create a physical disconnect from the battery to allow for safer maintenance

5.7 COLLECT USAGE DATA

- Implement a system whereby data can be collected, stored, and retrieved for later analysis.
- Such information should include, but not be limited to, the following information:
    - State of charge information
    - Velocity
    - Battery temperature
    - Operation of regenerative braking

5.8 DOCUMENT THE PROCESS

- In detail, present the procedure, struggles, failures, successes, and any other useful information related to the enhancement of the Lightning Riders' design.
- Update web site to chart the development of the project throughout the year.
- Provided time allows, create a detailed user manual for safe operation.

6 AVAILABLE TECHNOLOGIES

6.1 GENERATORS

In order to convert the currently all-electric motorcycle into a functioning hybrid vehicle, the most important thing will be to secure an appropriate gasoline-powered electric generator. In choosing an electric generator, we are faced with the unique and imperative problem of balance; in order for the bike to be ride-able, it must have an even weight distribution. This then poses the problem of generator placement. We can either elect to affix a single generator to the back of the motorcycle, or opt for two similarly-weighted generators on either side. If we buy 2 generators, we will have to draw more from our limited funds; however if we choose the single generator route, we might have greater difficulty in making the physical connection between the bike and generator and maintaining even weight.

Also, our choice of generator will be influenced by the choice between electric start and recoil start. A recoil start generator is started by physically pulling a ripcord. Obviously, this is not the most conventional way to start a motorcycle because the operator would have to first start the electric motor with a key and then step off of the bike to pull-start the gasoline engine. We would prefer to employ an electric start generator which we could then modify to start at the same time as the electric motor. One of the major drawbacks to this method is the fact that electric start generators are significantly bigger than their recoil start counterparts.

In this chart, we have detailed some generators that we could potentially use along with some technical information about them.

Company:	Model:	Start Type:	Power (W):	Fuel Capacity:	Run time[1]:	Dimensions:	Price:
DuroPower	DP1500s	Recoil	1500	1.1 gal	6hr	20”x15”x17”	$299.99
Briggs & Stratton	1532	Recoil	900	1.2 gal	6.4hr	20”x16”x17”	$599.95
Coleman Powermate	PC043155001	Recoil	1550	1.3 gal	6hr	20.25”x13.75” x17.75”	$449.99
Gentron	Pro2	Electric	3500	4 gal	11hr	23”x18.5”x19”	$399.00
Briggs & Stratton	30235	Electric	5550	5 gal	10hr	25.6” x22.9” x22.6”	$825.00
DuroPower	DP3500EC	Electric	3500	4 gal	8hr	24”x20”x20”	$429.00

6.2 USER INTERFACE

As of now, the user interface on the motorcycle is working. There is an available LCD screen on which information is displayed. One of our goals is to improve this user interface such that it will provide real-time information about power consumption, battery levels, current velocity, and projected range. In order to garner this information, we will need sensors to provide voltage and current information. These sensors are cheaply and readily available from electronic parts websites such as mouser.com.

6.3 ENHANCED CHARGING CIRCUITRY

In order for us to enhance the charging circuitry, the most easily available technology would be the previous charging circuitry. Last year’s Lightning Riders group designed a circuit for the charging system on a printed circuit board (PCB) and left enough space and etching on the board to construct a second identical circuit. Once we alleviate some of the problems with the existing circuit design, we would be able to wire up a second circuit in the same way. This would present us with a way of charging from two wall outlet plugs at the same time thus greatly decreasing our charge time.

6.4 DC-TO-DC CONVERTER

We want to use a DC-to-DC converter in order to power our microcontroller and various other electronics. These electronics require us to bring 72V down to various values below 12V. In order to do this, one option is to use a transformer. Transformers are very efficient devices but are large and prohibitively expensive, so that does not seem to be a very viable option. Another possibility would be a standard DC-to-DC converter circuit, like the PST-UDC/7212-9 manufactured by Powerstream. We could then fabricate our own circuit to convert the 12V to the various other values that we needed. Again, however, price is the limiting factor. Mindful of our budget, the most readily available option seems to be for us to construct our own DC-to-DC converter.

6.5 STREET LEGALITY

[1] Run time calculated at half load

According to the Motorcycle Operator Manual written by the Indiana State Bureau of Motor Vehicles, a street legal motorcycle must have a headlight, taillight, brake light, front brakes, rear brakes, turn signals, horn, and two mirrors. As of now, the bike is lacking all of these save for the rear brakes. Luckily, all of the rest of these can be found on motorcycle parts websites such as http://www.bikebandit.com/.

6.6 DATA CAPTURE AND STORAGE

There are a number of existing technologies that the group can leverage to accomplish its goals for the data capture and analysis portion of the project. Data capture and analysis can effectively be broken up into three separate sections: data storage, data analysis and data transfer. Each section will utilize different technologies.

6.6.1 DATA STORAGE

There are a variety of readily available, commercial data storage devices that will serve this purpose quite well. These include serial EEPROM ICs from Microchip along with microSD chips. Both flavors of data storage can function over a standard SPI interface and the number of chips can be scaled to meet the estimated data storage demand.

6.6.2 DATA TRANSFER

Once the data is captured in embedded memory it must be transferred to a personal computer for graphical and statistical analysis. This can be accomplished through the aforementioned SPI interface (allows transfer of data from storage back into the microcontroller) and then through the USART interface directly to the computer. Both interfaces are well known and easy to use. The connection between the microcontroller USART and the personal computer can be accomplished either through a physical cable directly linking the two devices or through a wireless Serial-to-Wifi (WiPort) converter made by Lantronix. The manufacturer has kindly donated a sample device to the team, thus eliminating the need to purchase one.

6.6.3 DATA ANALYSIS

Once the capability exists to transfer data to the personal computer it must be captured and analyzed. Microsoft provides free versions of its Visual Studio software (Express editions by programming language) and we will use one of these, Visual Basic Express or Visual C# Express, to develop the GUI for capturing data and conducting the analysis. Microsoft also has a free version of SQL Server (SQL Server Express) that may be harnessed to provide long-term data storage for data gathered from the microcontroller. The aforementioned Microsoft Visual Studio software interfaces nicely with connected serial ports, which nicely compliments the selection of data transfer hardware.

Each one of these areas has a readily available technological solution. Implementing these solutions

may not be easy, but it will not be because of a lack of technology. The technology exists to accomplish the group's goals; new technologies need not be invented.

7 ENGINEERING CONTENT

Modeling a real world setting, Electrical Engineering Senior Design emphasizes the importance of creating and implementing a unique, creative solution to achieve the goals of the specified project. Due to the hard work of the Lightning Riders, Hybrid's Angels have been left with a functioning electric motorcycle. Due largely to time constraints, the Lightning Riders were unable realize some finer, yet equally important, features of a hybrid design. Building upon the structure provided, Hybrid's Angels will enhance the existing design both in terms of performance as well as overall functionality.

7.1 FUNCTIONING SERIES HYBRID MOTORCYCLE

As the project currently stands, the system is a functioning electric motorcycle; however, it is not yet a hybrid system. As the name Hybrid's Angels implicitly suggests, this goal will be an essential part of the project. This challenge requires an insight into both the electrical and mechanical realms. First, it will be important to determine whether or not two generators will be prudent to mount on the current system. It may be preferable to select one generator with comparable power output to ultimately achieve better range and efficiency. Once the generator (or generators) has been mounted, it will be necessary to interface the generator to either charge the batteries or power the motor. Provided that the technology exists in the chosen generator for the given power specifications, Hybrid's Angels attempts to turn the generators on or off electrically based on the state of charge of the batteries or by user request.

7.2 ENHANCED CHARGING CIRCUITRY

Although apparently once functional, the charging circuitry of the motorcycle currently does not work as some critical components have been damaged. Among the first tasks of the Hybrid's Angels will be to develop a thorough understanding of the design that the Lightning Riders implemented. Upon the development of this firm understanding, the Hybrid's Angels will need to work within the confines of the current design to fix existing defects and improve the overall operability. Among the obstacles that must be overcome include the following:

- Troubleshoot and fix the circumstances that result in overheating and over-voltage conditions.
    - Develop ways to detect overheating and over-voltage conditions in order to prevent system inoperability.
- Switch the present configuration from triacs to SCRs as the triggered components due to the higher current and voltage ratings on SCRs that were purchased by the Lightning Riders.
    - The Lightning Riders believe that the triacs led to many of the performance issues observed during trial.

Still, the goal will remain to charge the six 12V batteries from either the wall socket or the generator system. In fact, the Hybrid's Angels, as did the Lightning Riders, desire to duplicate the functioning circuitry to allow for faster overall charging. By having two dimensions of charging, more current, and thus more power, can be drawn from standard outlets in a typical housing environment without tripping the breaker. Both of these circuits would theoretically work under the same microcontroller to power all six 12V batteries simultaneously. Mirroring the circuit in this fashion may or may not necessitate the revision of the current charging algorithm as the group intends to revise the existing code produced by last year's seniors. Hybrid's Angels hopes to write a code that would seamlessly adjust to single or double charging mode in addition to more intelligently and smartly charging the batteries. Additionally, this program should allow for automatic charging upon the presence of a 120VAC source.

7.3 DC TO DC CONVERTER CIRCUITRY

In its present configuration, the system electronics are powered from the 12V and 24V batteries in the 72V, six battery stack. As a result, these batteries are disproportionally taxed, leading to insufficient charging and general irregularities of these two batteries. In this light, it is desirable to power the electronics from all of the batteries simultaneously so that they are all sharing the responsibility of powering the electronics, which ended up consuming more resources than the Lightning Riders expected. It will be necessary to devise DC circuitry which will step-down the 72V input to more useful voltages for the electronics such as 24V, 12V, 10V, 5V, and 3.3V.

While charging, it would also be a nice feature to have the electronics be powered by the AC power source instead of draining the battery, which is trying to be charged. Obviously, this design would require the AC voltage to be converted to the useful DC values for the electronics.

7.4 INTERACTIVE USER INTERFACE

In order to create an interactive display which will inform the user of critical cycle information, a monitoring system will need to be implemented. This system should be capable of logging critical elements, such as temperature, voltage, and current drawn from the battery systems. These data elements will allow for real-time power, efficiency, range, and state of charge calculations. It will be an important design constraint to attach these sensors in a safe and stable fashion to prevent undue harm to both the user and the electronics. When the state of charge and range variables are clearly displayed to the user, the group would like to create a system where the user could start the generator via the interactive display. Ultimately, the ability to accomplish this engineering challenge will be based on the available budget constraints as well as the availability of a suitable electric start generator. Hybrid's Angels also aspire to implement a digital speedometer to replace the existing analog method.

7.5 MINOR PHYSICAL ADDITIONS

Although of minor importance, the Hybrid's Angels would like to additionally implement a few features to either enhance the safety or mission of the hybrid motorcycle. First and foremost, the group would like to implement a functional headlight, which the user could turn on or off from the control console. To make the design fully street legal, it will also be necessary to install front brakes, a taillight, brake lights, mirrors, and a horn. These devices will require a neat, orderly connection and wiring scheme. In order to further enhance the operation safety, the Lightning Riders indicated that it may be useful to create a physical disconnect on the battery stack, allowing for safer maintenance.

In the spirit of energy economy, the group would also like to implement an alternative energy source to power one of the electronic components. Preliminary thoughts on such an implementation would include utilizing solar technology or better harnessing the energy from the existing regenerative braking system. Incorporating an alternative source will be no small challenge, it will require a proper design to achieve the necessary ratings to power the given electronic device as well as a storage scheme when peak conditions are not present.

7.6 DATA COLLECTION

Steve Govea, the last remaining member of the Lightning Riders would also like to work on implementing an advanced data capture mechanism, whereby information can be collected, stored, and retrieved for later analysis. This collected information should include, but not be limited to, the following information: state of charge information, velocity, battery temperature, and operation of regenerative braking. Since many of these sensors are already in place, the most fundamental challenge will be creating a system to store these data variables. It would also be necessary to create a custom application in which to store this data on a PC as well as display it in a useful parsed format. The details of this portion of the project are detailed below with a brief description:

- Integrate an embedded serial-wireless device (WiPort) to provide wireless connectivity for transferring data to a PC. The WiPort mimics a standard serial port and the PC will see the devices connected through it as though they are physically connected. This is an entirely new aspect of the project and will likely require a significant integration effort to understand how this hardware works and how it should fit in with the existing system. A hard-wired backup should also be created in the event we experience network difficulties.
- Develop a custom Windows based application as the user PC interface. In addition, the communication protocol between the PC and microcontroller needs to be designed and tested. These are both entirely from scratch. As a general statement I believe that the Windows application should be developed in some version of Visual Studio due to its prevalence in the computing world.

- On-chip data storage, the nuts and bolts of this section. In addition to physical circuit layout for these devices the storage scheme developed during year one may need to be revised and simplified for ease of use.

In the end, the development of a data collection mechanism could allow for more intelligent program response for the charging circuitry, leading to a quicker, safer charge.

8 CONCLUSION

8.1 PROBLEM DESCRIPTION AND SOLUTION

Rising fuel costs have added an economic impetus to pursue green technologies which will lessen the world's dependence on fossil fuels. Unfortunately, the internal combustion engine has reigned supreme for decades. As a result, the proper time, effort, and money have not been invested into researching alternative sources of locomotion, thus leaving the world devoid of a logical successor to the internal combustion energy. To bridge the gap to this future technology, hybrid vehicles seem to be one of the logical alternatives to reduce the insatiable demand for oil. Hybrid's Angles intend to demonstrate the feasibility of making such a hybrid by building upon the electric motorcycle built by the Lightning Riders.

8.2 DEMONSTRATED FEATURES

Hybrid's Angels has undertaken the challenging task of demonstrating a host of features upon completion in May 2009. Most notably, the group intends to transform the current electric motorcycle into a functioning hybrid motorcycle. Hybrid's Angels have challenged themselves with a difficult set of task in order to take the most from the senior design experience.

8.3 AVAILABLE TECHNOLOGIES

Presently, a host of technology exists that could help the group achieve many of the outlined goals in this project. It will be important to assess whether or not these available technologies meet the design criteria of this project. Even if these criteria are met, the group will need to determine the most prudent fiscal solution to the design of the hybrid motorcycle.

8.4 ENGINEERING CONTENT

Due to the hard work and dedication of the Lightning Riders, a functional electric motorcycle exists for the Hybrid's Angels to build upon. To a certain degree, this existing model clearly makes the task of constructing a hybrid motorcycle much easier. For instance, Hybrid's Angels can observe design ideas that worked both well and not so well. Still, the learning curve will be significant as the group must gain insight into features and components designed by the Lightning Riders. This learning curve in itself will be a challenge similar to joining a task in the real world already in development. Of course, once the

proper level of understanding has been obtained, it will be no small task to develop a scheme to redesign some of the existing hardware and software involved in the bike. Perhaps most notable among these will be the alteration of the charging circuitry. Moreover, it will take considerable effort and engineering acumen to devise a system to capture, analyze, and display data taken from the system as well as make decisions based on this information. Adding to the complexity will be the task of interfacing an electric generator with the electric subsystem—not to mention mounting the generator. Not foreign to engineering will be the constraints imposed by the class budget on the project; this budget may very well limit the group's ability to make necessary additions to the project, such as an electric start generator. With that being said, the group intends to lobby the Energy Center for additional funding for this project. Naturally, the group in the end must develop a sufficient proficiency in hardware and software design as well as demonstrate an ability to make proper mechanical decisions.